February 6, 2020

MEMORANDUM

To: Western Regional Air Partnership Oil and Gas Working Group
From: John Grant, Kaity Lieschke and Amnon Bar-Ilan; Ramboll
Subject: Additional Reasonable Control Strategies for Oil and Gas Emission Sources in the WESTAR-WRAP region

1.0 Introduction

This memorandum provides information that agencies can use to support development of additional reasonable control strategies (ARCS) for sources in the upstream and midstream oil and gas (O&G) exploration and production sector in the Western States Air Resources Council-Western Regional Air Partnership (WESTAR-WRAP) region. Agencies are responsible for determining actual controls necessary to make reasonable progress toward natural visibility conditions at Class I areas as well as establishing emission limitations, compliance schedules, and other measures necessary to make reasonable progress in accordance with 40 CFR Section 308 (d)(1)(i)(A) of EPA's Regional Haze Rule.

1.2 Scope

The focus of this analysis is stationary O&G emission sources because stationary sources are typically under state/local agency jurisdiction. This analysis does not include mobile sources such as drill rigs or hydraulic fracturing engines since emission controls for mobile sources are typically under Federal jurisdiction. State agencies may consider mobile source controls to the extent that implementation of such control programs is feasible. ARCS may be accomplished by retrofits on existing emission sources and/or replacements of existing emission sources with lower-emitting technology.

The WRAP Reasonable Progress Source Identification and Analysis Protocol[1] recommends that "states should screen SO_2[2], SO_4[3], NOx[4] and non-fugitive PM-10[5] sources". This analysis focuses on controls applicable to NOx. Sources of SO_2 in the upstream and midstream O&G sector include amine units that are used to remove hydrogen sulfide (H_2S) from a sour gas stream. SO_2

[1] "WRAP Reasonable Progress Source Identification and Analysis Protocol For Second 10-year Regional Haze State Implementation Plans", WRAP Regional Haze Planning Work Group – Control Measures Subcommittee February 27, 2019. Accessed online in January 2020 at https://www.wrapair2.org/pdf/final%20WRAP%20Reasonable%20Progress%20Source%20Identification%20and%20Analysis%20Protocol-Feb27-2019.pdf
[2] sulfur dioxide
[3] sulfate
[4] nitrogen oxides
[5] Particulate matter less than 10 microns

controls are not discussed below because substantial SO_2 emission sources are emitted from certain local specific sour gas fields and at specific gas plants, rather than across the region as is the case for NOx. Agencies should review SO_2 emissions from O&G sources in their jurisdiction to determine whether to estimate emission reductions from ARCS for these sources. SO_4 controls are not discussed below because SO_4 emissions are not directly estimated in O&G emission inventories. PM_{10} controls are not discussed below because PM_{10} emissions contributions from the O&G sector are typically small compared to other sectors such as on-road mobile.

2.0 NOx Emission Sources

NOx emissions from stationary O&G sources result from both internal combustion sources (e.g., engines and turbines) and external combustion sources (e.g., heaters and flares). NOx emission contributions are described below based on the medium scenario, "Continuation of Historical Trends", future year emission inventory[6].

51% of NOx emissions are from nonpoint sources and 49% are from point sources. As shown in Figure 1, substantial nonpoint emission sources include well-head engines (61%), hydraulic fracturing engines (17%), flaring (9%), heaters/reboilers (7%), and drill rigs (5%). As shown in Figure 2, substantial point source emissions include natural gas (NG) turbines (31%), sources for which no description is available (16%), NG engines with no information available on engine type (16%), lean burn NG engines (13%), rich burn NG engines (11%), heaters/reboilers (5%), and coal conveyors (5%). 100% of NOx emissions from coal conveyors are from the Great Plains Synfuels Plant located in Mercer County, North Dakota. The Great Plains Synfuels Plant converts lignite coal into natural gas for use in electricity generation and home heating.

[6] Grant, J., R. Parikh, A. Bar-Ilan, 2019. Final Report: 2028 Future Year Oil and Gas Emission Inventory for Westar-Wrap States - Scenario #1: Continuation of Historical Trends. Ramboll. Prepared for the Western Regional Air Partnership Oil and Gas Workgroup. Accessed online in January 2020 at https://www.wrapair2.org/pdf/WRAP_OGWG_2028_OTB_FinalReport_11Oct2019a.pdf. Fully detailed inventory spreadsheet available at https://www.wrapair2.org/pdf/WESTAR_OGWG_Future_Emissions_Inventory_webdist_101419_nolink.xlsx

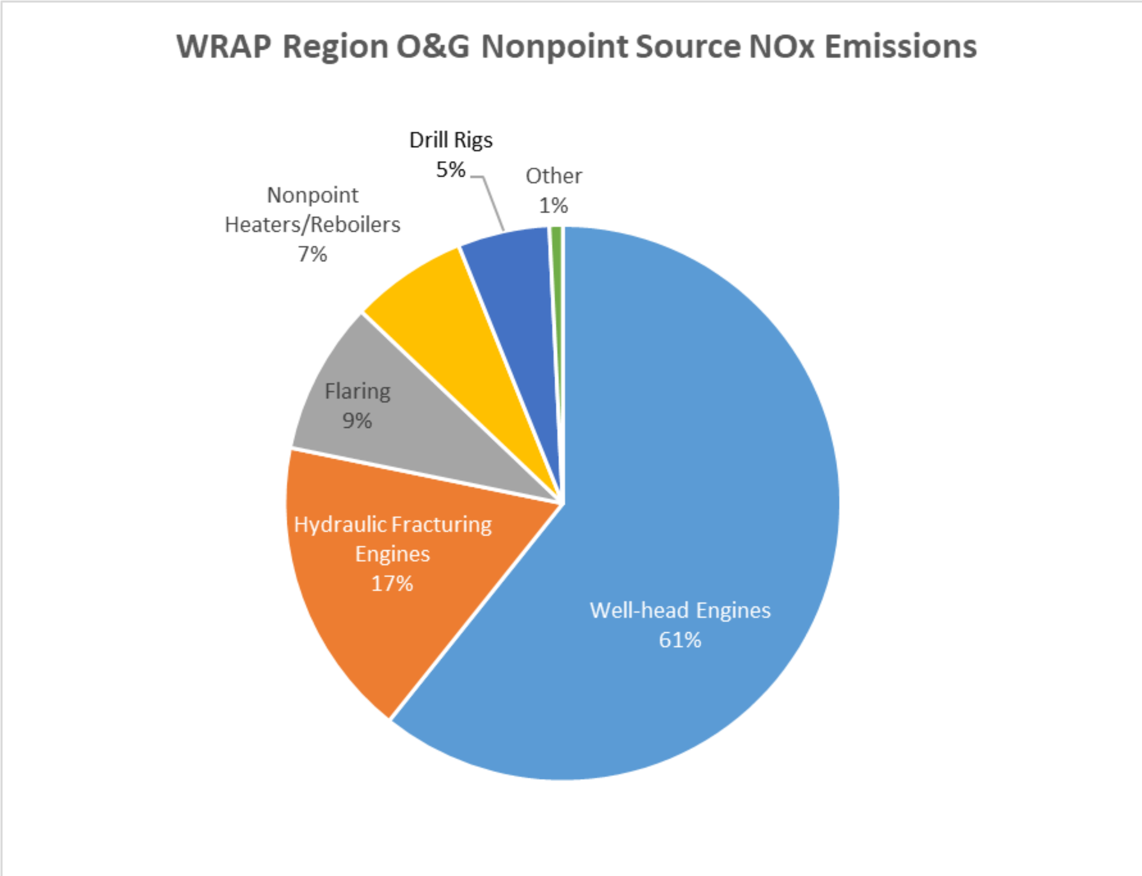

Figure 1. **WRAP region O&G nonpoint source NOx emissions (source: WRAP OGWG medium scenario, "Continuation of Historical Trends", future year emission inventory[6]).**

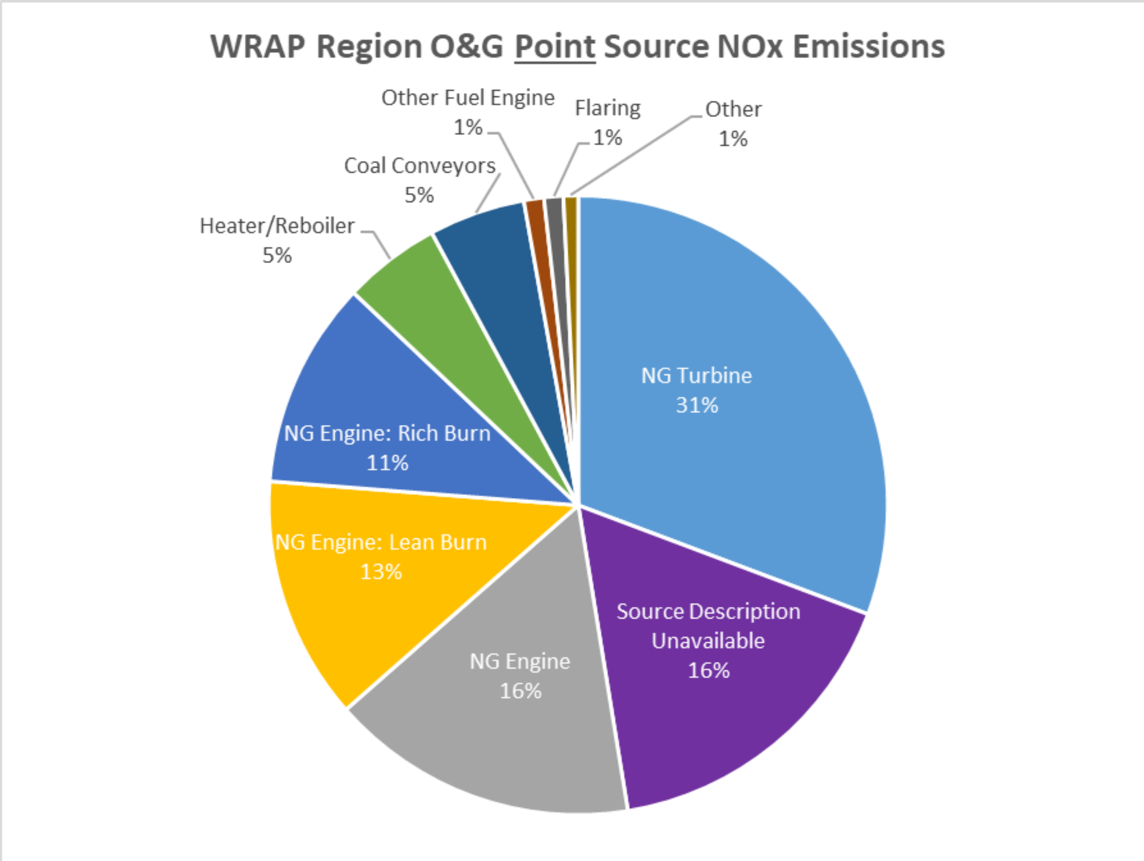

Figure 2. **WRAP region O&G point source NOx emissions[7] (source: WRAP OGWG medium scenario, "Continuation of Historical Trends", future year emission inventory[6]).**

Emission contributions by source category are shown by state and tribal/non-tribal jurisdiction in Table 1 for states with substantial NOx emissions from O&G sources. States without substantial NOx emissions from O&G sources are not shown (i.e., Arizona, Idaho, Oregon, Nevada, Washington, South Dakota).

[7] All emissions from coal conveyors are from the Great Plains Synfuels Plant located in Mercer County, North Dakota. The Great Plains Synfuels Plant converts lignite coal into natural gas for electricity generation and home heating.

Table 1. WESTAR-WRAP region O&G NOx emissions for each State by source category for states with substantial O&G emissions (source: WRAP OGWG medium scenario, "Continuation of Historical Trends", future year emission inventory[6]).

Source Category	AK (non-tribal)	CO (non-tribal)	CO (tribal)	MT (non-tribal)	MT (tribal)	ND (non-tribal)	ND (tribal)	NM (non-tribal)	NM (tribal)	UT (non-tribal)	UT (tribal)	WY (non-tribal)	WY (tribal)
Point Sources													
NG Turbine	30,069	602	240	105	0	2,285	0	6,071	980	358	0	1,294	0
Source Description Unavailable	0	0	0	0	134	0	1,801	21,253	445	0	0	2	159
NG Engine	165	6,588	3,571	972	0	3,037	0	3,893	12	112	0	3,322	0
NG Engine: Lean Burn	1,716	467	0	0	0	0	0	11,390	270	1	0	3,278	0
NG Engine: Rich Burn	333	2,009	0	189	0	201	0	5,480	55	2,001	3,551	1,553	0
Coal Conveyors [7]	0	0	0	0	0	7,168	0	0	0	0	0	0	0
Heater/Reboiler	891	423	89	35	0	935	0	1,100	3	912	1,850	723	0
Other Fuel Engine	1,219	162	0	2	0	54	0	0	0	0	0	51	0
Flaring	330	395	0	3	0	17	0	236	10	14	13	415	0
Other	78	172	19	0	0	360	0	147	0	82	195	28	0
Point Sources Total	**34,800**	**10,818**	**3,920**	**1,306**	**134**	**14,058**	**1,801**	**49,568**	**1,775**	**3,479**	**5,609**	**10,665**	**159**
Source Category	**AK (non-tribal)**	**CO (non-tribal)**	**CO (tribal)**	**MT (non-tribal)**	**MT (tribal)**	**ND (non-tribal)**	**ND (tribal)**	**NM (non-tribal)**	**NM (tribal)**	**UT (non-tribal)**	**UT (tribal)**	**WY (non-tribal)**	**WY (tribal)**
Nonpoint Sources													
Well-head Engines	1,600	7,391	10,725	2,811	131	25,720	3,209	33,481	3,034	880	111	1,889	6
Hydraulic Fracturing Engines	0	0	18	82	0	10,112	1,579	8,775	1	0	0	5,641	0
Flaring	1	101	0	189	1	9,067	1,717	1,165	6	1	0	1,019	0
Nonpoint Heaters/Reboilers	80	1,880	266	337	8	1,629	172	1,393	83	386	14	3,868	6
Drill Rigs	219	0	14	117	16	3,720	575	2,136	3	26	3	1,062	0
Other	962	0	27	0	0	0	0	95	16	40	1	17	0
Nonpoint Sources Total	**2,862**	**9,371**	**11,050**	**3,536**	**156**	**50,248**	**7,252**	**47,045**	**3,143**	**1,333**	**129**	**13,496**	**13**

The following sources will be evaluated for controls since these sources are the stationary sources that make the most substantial contributions to the WRAP region O&G NOx inventory:

- Natural gas-fueled well-site and midstream engines
- Natural gas-fueled turbines
- Flares
- Natural gas-fueled heaters/reboilers

As mentioned above, mobiles sources such as drill rigs and hydraulic fracturing engines are substantial NOx emitters, but controls for these sources will not be evaluated since these are mobile sources and are typically under federal jurisdiction.

3.0 Controls

This section includes a representative list of controls, key metrics for evaluating these controls, and references to guidance documents consulted in this analysis. The list of controls included herein is not intended to be comprehensive. Other applicable control strategies, not listed in this section, may be designated by agencies to make reasonable progress towards natural visibility at Class I areas in accordance with 40 CFR Section 308 (d)(1)(i)(A) of EPA's Regional Haze Rule. This section presents generic cost factors based on the reference guidance documents. In the case that states choose to develop source-specific cost factors, they should do so consistent with methodology described in EPA 2019 Guidance[8].

Resources consulted to develop the representative list of controls and associated metrics are listed below.

- EPA Control Strategies Tool (CoST)[9]
- EPA "Guidance on Regional Haze State Implementation Plans for the Second Implementation Period"[8]
- EPA Menu of Control Measures for NAAQS Implementation[10]
- EPA "Assessment of Non-EGU NOx Emission Controls, Cost of Controls, and Time for Compliance Final TSD"[11]

For the ARCS analysis, controls are to be evaluated according to the four-factors listed below. With respect to evaluation criteria, EPA's 2019 Guidance states that high cost of compliance, adverse energy and non-air quality impacts or short remaining useful life "may weigh in the

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[8] Accessed online in December 2019 at https://www.epa.gov/visibility/guidance-regional-haze-state-implementation-plans-second-implementation-period

[9] Accessed online in December 2019 at https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-analysis-modelstools-air-pollution#control%20strategy%20tool

[10] Accessed online in December 2019 at https://www.epa.gov/sites/production/files/2016-02/menuofcontrolmeasures.xlsx

[11] Accessed online in January 2019 at https://www.epa.gov/sites/production/files/2017-05/documents/final_assessment_of_non-egu_nox_emission_controls_cost_of_controls_and_time_for_compliance_final_tsd.pdf

direction of not including a particular control measure,… [EPA recommends] that states consider the time necessary for compliance as part of their determination of what compliance deadlines for selected control measures are reasonable, rather than as part of their determination whether to adopt the control measures".

1. **Costs of compliance**: We have included generic cost effectiveness estimates below for each control measure based on the reference sources listed above which account for average capital, operation, and maintenance costs. Cost effectiveness is expected to vary by source according to parameters such as remaining useful life, installation costs, and fuel costs. The reference cost estimates were compiled over approximately the last decade and should be considered average estimates that do not consider current fuel or other commodity prices or technology costs. EPA documentation notes the following with respect to costs:

    > *the costs of applying a given control measure will have case-specific considerations. While the tables here provide overall control costs and control efficiency estimates derived from the references, there is inherent uncertainty in any estimates of this nature. We do not attempt in these tables to provide any rigorous treatment of these uncertainties, but rather provide the control efficiency and cost estimates as a rough "ballpark" starting point.*[12]

2. **Time necessary for compliance**: As indicated above, 2019 Draft Guidance states that whereas the three factors should be considered for deciding on which control factors to apply, [EPA recommends] "that states consider the time necessary for compliance as part of their determination of what compliance deadlines for selected control measures are reasonable". Information was not readily available from reference sources on typical installation times required for equipment associated with most control strategies listed below. EPA's "Assessment of Non-EGU NOx Emission Controls, Cost of Controls, and Time for Compliance Final TSD" does indicate that 6-8 months is required for installation of a low-NOx burner for turbines and heaters/reboilers.
3. **Energy and non-air quality environmental impacts:** 2019 Draft Guidance indicates that direct impacts on energy consumption at the source should be considered in cost calculations, but indirect energy inputs needed to produce raw materials for construction of emission control devices should not be included in cost calculations. 2019 Draft Guidance also recommends that states consider non-air quality environmental impacts in cost estimates such as water use, waste disposal of catalyst reagent, etc. As noted above, we have included generic cost estimates from reference data sources which are expected to include average costs associated with energy and non-air quality environmental impacts. We have included notes on energy and non-environmental impacts below for each measure, to the extent feasible.

[12] "Important Information Concerning the Menu of Control Measures", accessed in January 2020 online at https://www.epa.gov/sites/production/files/2016-02/documents/menuofcontrolmeasures.pdf

4. **Remaining useful life**: EPA recommends that states consider remaining useful life by using it to calculate emission reductions, annualized compliance costs, and cost per ton estimates. Average costs included in this analysis assume the useful life based on the reference documents. Generic estimates of useful life are 30-40 years for reciprocating engines, 45 years for gas turbines, and 30 years for process heaters[13]. Useful life estimates were not readily available for flares or enclosed combustion devices.

Table 2 shows generic control strategy metrics that agencies may consider in development of the ARCS for turbine, reciprocating engines, heater/reboilers, and flares. As indicated in Table 1, estimates of control efficiency and cost effectiveness were not readily available for replacement of flaring or enclosed combustors.

[13] EPA 2011v6.3 Modeling Platform Technical Support Document.

Table 2. Control strategy metrics.

Control Measure	Applicability Range	Average Cost per Ton of NOx Reduction ($/ton)	Control Efficiency	Energy and Non-Air Quality Environmental Impacts
Natural Gas Turbines				
Low NOx Burner	NOx<1tpd	$490	68%	-
	NOx>1tpd	$100	84%	
Selective Catalytic Reduction and Low NOx Burner	NOx<1tpd	$4,125	94%	-
	NOx>1tpd	$963	94%	
Selective Catalytic Reduction and Steam Injection	NOx<1tpd	$3,226	95%	steam and energy requirements
	NOx>1tpd	$1,348	95%	
Selective Catalytic Reduction and Water Injection	NOx<1tpd	$4,382	95%	water and energy requirements
	NOx>1tpd	$1,814	95%	
Steam Injection	NOx<1tpd	$1,669	80%	steam and energy requirements
	NOx>1tpd	$802	80%	
Water Injection	NOx<1tpd	$2,423	76%	water and energy requirements
	NOx>1tpd	$1,172	76%	
Natural Gas Reciprocating Internal Combustion Engine (Rich Burn)				
Non-Selective Catalytic Reduction	-	$509	90%	-
Natural Gas Reciprocating Internal Combustion Engine (Lean Burn)				
Low Emission Combustion [d]	2-cycle engines only	$628	87%	-
Natural Gas Heater/Reboiler				
Selective Non-Catalytic Reduction [e]	NOx<1tpd	$6,211	50%	-
	NOx>1tpd	$2,520	50%	
Low NOx Burner [f]	≤50 MMBTU/hr	$10,661 - $42,644	50%	-
Low NOx Burner and Flue Gas Recirculation	NOx<1tpd	$4,109	60%	-
	NOx>1tpd	$947	60%	

Control Measure	Applicability Range	Average Cost per Ton of NOx Reduction ($/ton)	Control Efficiency	Energy and Non-Air Quality Environmental Impacts
Flare or Enclosed Combustor				
Vapor Recovery Unit (storage tank)	-	Not readily available [a]	up to 100%	Fossil fuel or electricity consumption associated with small reciprocating engine typically used in these systems.
Onsite Power Generation	-	not readily available	Variable [b]	-
Connecting Oil Well Associated Gas to Gathering Pipeline	-	variable [c]	up to 100%	-

[a] VOC cost effectiveness estimates for VRUs applied to uncontrolled tanks range from $1,065 to $14,734. For a given flare, the mass of NOx reduced based on replacement of a flare with a VRU is typically expected to be two or more orders of magnitude lower than the mass of VOC reduced based on replacement of a flare with a VRU. Therefore, cost effectiveness for replacement of a flare with a VRU is expected to be greater than 100,000 $/ton of NOx.

[b] Only in the case of a highly controlled turbine or reciprocating engine are NOx emission reductions expected for onsite power generation replacement of flares or enclosed combustors.

[c] Dependent on site specific infrastructure requirements, range estimate not readily available.

[d] Application of low emission combustion firing techniques

[e] Heaters/reboilers used in upstream and midstream O&G applications are typically too small for cost-effective application of non-selective catalytic reduction, but can be evaluated on a case-by-case basis.

[f] Cost effectiveness estimates are lower for heaters or reboilers with a rating greater than 50 MMBTU/hr; however, heaters or reboilers with a rating greater than 50 MMBTU/hr are not provided in this table because they are not typically used in upstream or midstream O&G operations.

4.0 Implementation

In this section, we describe how agencies can use information in this memo to determine ARCS necessary to make reasonable progress toward natural visibility conditions at Class I areas. A companion spreadsheet is also being issued with this memo which agencies may fill-out and return to the WRAP OGWG co-chairs to document agency-selected control strategies and emission reductions.

Below are important points to consider when developing ARCS.

- **Jurisdiction:** ARCS are to be applied to only to sources within each agency's jurisdiction. Tribal emissions are considered separately from non-tribal emissions due to separate jurisdiction on tribal and state lands.
- **Reference Inventory:** NOx emission reductions are to be estimated by agencies with respect to the 2028 medium forecast emission inventory[6].
- **Applicability:** ARCS are applicable to control emissions above and beyond controls already required by on-the-books regulations.

Each agency should calculate potential emission reductions from selected ARCS that could apply in their jurisdiction and provide an estimated potential NOx emission reduction. Suggested steps for agencies to take to estimate ARCS are listed below.

1. Identify the emission source and/or facility combination to which ARCS can be applied. Review of the 2028 medium forecast emission inventory spreasheet[6] may be useful to select sources with substantial emissions.
2. Identify the current level of control for the sources to which ARCS will be applied. Agency databases must be consulted to identify current controls on point sources. Basin-level nonpoint source control assumptions are described for many sources in the 2028 medium forecast emission inventory report[6].
3. Select ARCS applicable to agency chosen emission source(s) and estimate NOx emission reductions.
4. Identify the useful life remaining on the emission source(s) to which the controls will be applied.
5. Document assumptions about chosen control strategies in the companion spreadsheet provided with this memorandum and return it to WRAP OGWG co-chairs.
6. The WRAP OGWG Co-Chairs will compile the agency submitted ARCS spreadsheet(s) as a deliverable to the Control Measures Subcommittee of the Regional Haze Planning Work Group for use in the "Potential Additional Controls" modeling scenario.